

# Characterising patterns of engagement of different participants in a public STEM-based analysis project

Jane Essex <sup>a\*</sup> and <sup>b</sup> Katherine Haxton

*<sup>a</sup> School of Education, University of Strathclyde, Glasgow, U.K.: <sup>b</sup> Department of Chemistry, University of Keele, Newcastle-under-Lyme, U.K.*

Lecturer in Chemistry  
School of Education  
University of Strathclyde  
141 St James Road  
Glasgow  
G4 0LT

Tel: +44 (0)141 444 8100

Email: [Jane.essex@strath.ac.uk](mailto:Jane.essex@strath.ac.uk)

Twitter: [@jane\\_essex](https://twitter.com/jane_essex)

ORCID identifier: 0000-0002-9938-8134

Jane Essex is a lecturer in science education who has previously worked in science teacher education at the University of Keele and Brunel University. Having led considerable science outreach initiatives over the last 15 years, she was shortlisted for STEMnet Outreach Ambassador of the Year in 2016.

Dr Katherine Haxton  
Department of Chemistry  
University of Keele  
Keele  
Newcastle-under-Lyme  
ST5 5BG

Telephone 01782734209

[k.j.haxton@keele.ac.uk](mailto:k.j.haxton@keele.ac.uk)

ORCID identifier: 0000-0001-9812-4324

Twitter: [@kjhaxton](https://twitter.com/kjhaxton)

Katherine Haxton is a Senior Lecturer in Chemistry at the University of Keele. She obtained her PhD in 2004 for 'Silsesquioxane Dendrimers as Catalysts: Synthesis and Molecular Modelling', then moved to the University of British Columbia, Canada. Katherine has undertaken extensive science outreach work with a wide variety of participants.

## Abstract

A STEM (science, technology, engineering and mathematics) analysis project undertaken in the context of a historic visitor site is described. The project offered different types of opportunity for scientific working, and involved four distinct groups of participants. Two distinguishing features of the different groups of participants were their primary motivation for engagement with the activity, and their level of previous engagement with formal **STEM** education. Participants in different parts of the project were assessed as to their level of science capital (Archer et al., 2015). Drawing upon engagement theory, the observable behaviours were used as an indicator of engagement and then categorised according to Barriault and Pearson's (2010) taxonomy. The analysis showed that learner engagement was exhibited at different levels by the different categories of participants, with higher levels of engagement exhibited by participants with a higher level of science capital. Although there was general correlation between the level of science capital and the proportion of higher engagement learning behaviours, one group of participants deviated from this trend. The findings indicate that the level of science capital is a key determinant of engagement and associated learning behaviours, but did not completely account for participants' engagement in the science outreach activity.

**Key words** Outreach; science capital; engagement theory; learning behaviours

## Introduction

Following a surge in visitor interest in the pharmacy shop at their re-constructed Victorian town at Blist's Hill, Shropshire, U.K., the Ironbridge Gorge Museum Trust's trustees re-evaluated the risk that the collection might pose to visitors, volunteers and staff. An initial response had been that disposal of the entire collection might be the surest way to guarantee everyone's safety. However, no decision could be made until the identities of the contents of the jars, which numbered over 300 in total, had been established. The request to university partners to assist with the identification gave rise to a combined STEM analysis and outreach programme to which participants with very varying levels of knowledge contributed. The range of analytical approaches used, combined with the consideration of the ways in which the substances had originally been used, was felt to offer elements of chemical technology and engineering, in addition to scientific components and thus it was termed STEM, rather than purely science outreach.

The project described here comprised analysis of the contents of a pharmacy collection, used as a means of **STEM** outreach, was based in a museum intended to demonstrate Victorian town life. Despite the apparent mis-match between the venue's aims and the focus of the project, the participants exhibited a wide range of formal STEM education. The chemical identities of the substances were unknown but needed by the museum to determine the fate of the collection. The work thus had an outside ('authentic') focus (Kearsley & Schneiderman, 1999). The authenticity alongside the elements of scientific challenge, sensory dimension, novelty and interactivity of the work fulfilled the criteria for engaged learning, according to O'Brien & Toms (2008) and Berger, Rugin & Woodfin (2014). Similarly, the social and functional features of the work undertaken by participants fulfilled another engaged learning model, summarised as 'relate-create-donate' (Kearsley & Schneiderman, 1999). The voluntary nature of participation meant that interaction was learner-led, in line with more recent refinements to the learning engagement model (Berger, Rugin & Woodfin, 2014), although the undertaking of actual analysis could not be done without some restrictions, due to health and safety considerations.

The impact of **STEM** outreach work and learning in informal settings such as museums has been evaluated previously (Chi, Dorf & Reisman, 2015) and found to be effective in engaging a lay

audience's interest. More significantly, such work offers one means of achieving the so-called '95% solution' desired to develop scientific knowledge in the general population (Falk & Dierking, 2010). As Falk, Moussouri & Coulson (1998:278) note, 'Generic venues therefore offer strong potential for informal science engagement'. The extent to which different visitors might be engaged with outreach at a generic site was not, however, considered by the authors.

The impact of the outreach work upon participants' learning can be assessed by an analysis of observed learning behaviours, such as that described in Barriault and Pearson's (2010) taxonomy (2010). The taxonomy of observed behaviours was used in this study as an indicator of engagement, in order to investigate the question:

- What are the key features for characterising different participants in a **STEM** outreach activity at a non-STEM venue?

The work here was conceived as a piece of evaluation research, looking at the applicability of Barriault and Pearson's (2010) framework to different groups of participants in **STEM** outreach events. Its primary purpose was to test the applicability of a published framework in a new context, which would potentially facilitate the further application of the framework, for instance in the classroom or to extra-curricular activities. However, the research was not simply evaluation, with the associated short-term outcomes, nor was it subject to political agendas (Kelley and Knowles, 2016), which commonly mark out evaluation studies. The study sought additionally to understand the underpinning causes of observed differences in engagement with learning opportunities. The latter component of the work was intended to probe factors affecting voluntary participation in STEM activities, with the idea of enhancing involvement. The analysis of observed learning behaviours was undertaken by use of quasi-experimental analysis of participants (Ryan & Cousins, 2009), within the limits of the disclosure made to the researchers (JE and KH) who were conducting the outreach.

### **Opportunities for engagement with STEM furnished by visitor centres**

The features which make an activity engaging are widely agreed upon and these are combined in O'Brien and Tom's (2008) Conceptual Framework of User Engagement; there is, moreover, a large corpus of empirical evidence that supports the validity of the components of the framework within STEM work. For example, affective responses are known to be an important determinant of engagement, which is intimately related to 'a strong affective dimension: feelings and emotions, pleasure, satisfaction and dissatisfaction are important drivers' (Watts, 2015: 353). Correspondingly, positive affect responses are recognized in the Conceptual Framework of User Engagement as an attribute of engagement (O'Brien and Toms, 2008). Another example of the concordance found between O'Brien and Tom's framework (2008) and empirical findings on science learning at visitor centres is the necessity of 'challenge'. In other words, there needs to be a suitable level of cognitive demand (Ateh & Charpentier, 2014; de Witte & Rogge, 2012). O'Brien and Toms (2008) further refine the need for challenge to make an activity engaging and deserving of attention, asserting that it tends to be recognized by the participant during a period of temporary disengagement from the activity.

The visitor centre as a venue can be a key contributor to participant engagement, providing as it does a physical context for learning, the third component of Falk and Dierking's (2000) model of parameters which contribute to individual engagement. A memorable venue provides both the necessary aesthetic and sensory appeal to promote engagement (O'Brien & Toms, 2008). The deployment of what is termed 'sensory appeal' in the user engagement framework finds almost universal expression in STEM outreach activities, which usually involve practical work, a

recommended approach to bringing about engagement with science (Campaign for Science and Engineering, 2014) including by those with a low level of 'scientific capital' (Archer et al., 2015).

It has been previously documented that learning can comfortably co-exist with entertainment, as so-called 'edutainment'. (These same co-existing outcomes find corresponding representation in O'Brien and Toms' (2008) Conceptual Framework of User Engagement as 'novelty' and 'interest'). Indeed, this duality of outcomes may be a great strength of museums and similar visitor centres (Falk, Moussouri & Coulson, 1998). 'Visitor centre science' venues commonly place **STEM** in a socio-cultural context and the combination of socio-cultural and scientific elements may indeed be an important factor behind the decision to visit such venues (Missouri, 2002). There is also a raft of findings demonstrating that learners can experience a higher level of motivation with respect to STEM that has a relevant socio-cultural context. For example, studies have shown that children's recall of content is improved, and enhances the persistence of learning, by having the content embedded in a socio-cultural context (Stevenson, 1991; Istamina, 1948). In this way, visitor centre visits can put STEM 'firmly into social, industrial and historical contexts' (Braund & Reiss, 2004: 117). A similarly positive effect has been observed in formal learning situations (Vaino, Holbrook & Rannikmäe, 2012). Indeed, some would argue that only science with a socio-cultural dimension offers a true and holistic picture of authentic science (Erduran & Dagher, 2014; Irzik & Nola, 2014). There is a caveat about the necessity of congruence of the science and cultural contexts, however, in that it is necessary to make the activities relate to the site as far as possible, rather than being a disconnected 'bolt on' in order to meet initial visitor expectations (Sheng & Chen, 2012). Such findings all support engagement theory's tenet of the centrality of meaningful engagement to effective learning (Kearsley & Shneiderman, 1999). These findings underline the potential impact of visitor centre science in engaging the public in STEM learning, especially those who self-identify as non-scientists, to undertake STEM learning (Falk & Dierking, 2000). The non-scientists may participate despite having visited for purposes such as cultural entertainment, personal identification and historical reminiscence (Day & Bryce, 2013; Sheng & Chen, 2012). One potential disadvantage of contextualised **STEM** is that it risks causing processing overload, although there is no empirical evidence of this problem occurring at visitor centres (Fox, Park & Lang, 2007; Johnstone, 1991).

### **Characterising participants in STEM activities**

The 'science capital' of visitors is a composite measure of both past and potential future engagement with scientific activities which builds upon Bourdieu's (1986) model of how individuals gain advancement in society. It takes account of social, economic and cultural capital (or resources which can be used for advancement) relating to formal science and, by implication to the cognate subjects of technology, engineering and mathematics (Archer et al., 2015; Bull et al., 2003). Such capital helps to shape an individual's habitus (or internal disposition), and can bring both academic success and employment opportunities within the fields (or contexts) of formal education and the workplace. The level of prior **STEM** learning, both in formal and informal contexts, is a crude indicator of science capital, but one which can be readily ascertained. Those who possess greater levels of science capital are more likely to voluntarily participate in a STEM-related outreach activity (Coffee, 2008), possibly because, beyond their science capital they also possess a high level of linguistic capital (Stanton-Salazar & Dornbusch, 1995) and psycho-social capital. These factors will all contribute to the observation that such participants also experience a higher level of learning during the activity. This illustrates how, '.... capital can generate (more) capital.' (Archer et al., 2015: 294). It would, therefore, be expected that participants in the STEM outreach are unrepresentative of the wider community. This is a major methodological weakness in working with a self-selecting group of

participants in a **STEM** activity. Those visitors to the museum who are already mindful of the privilege afforded by successful participation in **STEM**, for example the necessity of science GCSE to gaining the English Baccalaureate and the career opportunities associated with post-compulsory STEM qualifications, will be positively disposed towards the science enrichment activities that are available (Archer & De Witt ,2012; Archer, De Witt & Willis, 2014 ).

As Archer et al. posit that science cultural is an extension of cultural and social capital, these self-selecting participants possess, by definition, social and cultural capital. However, all visitors to a museum may also be considered to have appreciable levels of social and cultural capital embodied in the knowledge, consumption and social networks associated with undertaking such a visit. What varies between these visitors is the relative impact of general social and economic capital and, specifically, the science capital upon their decision to engage with the analysis activity at the museum. Whilst the trajectory component of scientific capital cannot be assessed during a brief outreach activity, the level of cultural capital embodied in qualifications may be readily ascertained during a brief conversation.

### **Assessment of engagement**

Any engagement with learning results in multiple impacts which prelude the use of a simple measure of impact (Barriault, 1999; Burns, 2003; Williams & Wavell, 2001). Similarly, the range of cognitive changes effected through engagement with outreach activities can be at several different levels and detailed assessment would be required to ascertain which ones had been achieved. Affective responses elicited may also be very varied. For instance, they may include enjoying the **STEM**, being interested in **STEM** and becoming voluntarily involved with **STEM**. In the face of this wide range of possible outcomes, Barriault (1999) developed a taxonomy of indicators of involvement with outreach activities, based upon the 'observable behaviours' of participants. Such behaviours provide indirect evidence of the kinds of affective and cognitive responses elicited by outreach activities that are considered to denote learning. This taxonomy provides an auditing tool that Barriault and Pearson (2010) used to assess the impact of different types of outreach activities. Although their framework still requires subjective interpretation by the observer, for instance of body language, and so may be susceptible to researcher bias, the taxonomy gives a structured and explicit tool with which to indirectly assess the engagement and learning of participants. The level of engagement may, in turn, be taken as an indicator of habitus, or disposition towards scientific activity (Archer et al., 2015). However, it should be noted that low engagement behaviour cannot be taken as synonymous with low levels of **STEM** capital; it, for instance, conceivable that a visitor with a high level of science capital would refrain from the activity either to give other visitors better access or because they considered the activity too simple for them.

The three categories of learning behaviour are:

1. *Initiation*. The learner shows tentative engagement with the activity, sufficient to gain an outline idea of the concepts being demonstrated and to start a learning experience. Such behaviours might include stopping to look at the activity, trying the activity out for the first time.
2. *Transition*. The visitor shows a positive affective response to the activity and a sustained engagement with the activity. Such behaviours are considered to denote a higher level of learning than those of initiation learning behaviours. Smiling or commenting positively on the activity and repeating the activity are examples of transition learning behaviours.
3. *Breakthrough* behaviours are those that demonstrate the value of the learning opportunity to the visitor and their everyday life. Such behaviours also demonstrate the desire to explore

the concepts being expostulated by the activity further. Examples of this category of higher order learning behaviour include relating the activity to previous experiences, sharing information, seeking to gain further information or understanding than was first presented. (Barriault, 1999)

Other measures of engagement, such as Ponciano and Brasileiro's (2015) have also been devised, which enable the researcher to quantify engagement over a more extended activity, but Barriault and Pearson's taxonomy is especially useful in a 'drop in' session, because it can be used to analyse engagement over brief periods of engagement.

### **The Victorian pharmacy project protocol**

Based on a preliminary visit by the researchers and an audit of the collection, including the labels on the bottles where extant, the original contents of around a half of the bottles were surmised. Using these putative identities, the researchers were able to plan appropriate confirmatory tests. Initial analyses were carried out at the museum using visual examination; flame testing on mobile Bunsen burners and classical chemical testing with solutions in micro-scale dropper bottles. The researchers conducted a series of chemical analysis days, to which the general public contributed. In order to ensure their safety, participants at the museum were asked to test reference standard substances whilst university staff tested the corresponding unknown substances from the collection in parallel. All members of the public who provided assistance at the museum site had come primarily to visit the museum site, rather than to work on the analysis project. All the participants were asked about their scientific knowledge. Only one of them disclosed any post-compulsory study of science and it appeared that the visitors had a low level of science capital. In addition, a school group of 14-15 year olds, who were studying a vocational science course, was brought to assist at the museum; the chance to carry out the analytical techniques about museum exhibits in the museum setting had been the main attraction for the teacher, who otherwise would have carried out the same activities in the school lab.

Samples of substances which did not lend themselves to easy or safe analysis by the public, were removed to university labs for investigation by participants, who had either responded to an invitation to attend a university-based analysis day, or had approached the university for work experience, and accepted the offer of working on the project for a week. These participants were planning to embark, or had already done so, on optional post-16 study of Chemistry ('A' levels or under-graduate qualifications). The focus of these participants was the development of transferable skills combined with the furtherance of their analytical knowledge; the context for the analysis was of secondary significance to them (Essex, 2013).

## **Methodology and methods**

### **1. Ethicality of the study**

Because the evaluation of the framework of observable behaviours was of potential benefit to providers of **STEM** outreach and their audiences, the work adhered to the ethical requirement to maximise benefit to all participants (Strike, 1990). In line with the expectations of evaluative research, the work showed equal respect for all subjects, in this case by considering all behaviours and learning experiences to be of equal importance in the analysis and its subsequent applications. By only gathering data with informed consent, the study also upheld the autonomy of the subjects who had volunteered to work on the analysis project (Suchman, 1967).

The research conformed to the expected standards of ethicality set out in the British Educational Research guidelines (2014) in that participants' consent for the use of their image and feedback was obtained. Participation was voluntary and there was no disadvantage incurred by withdrawing from participation; if students working at the university had indicated that they wished to withdraw from the project, alternative activities were available to them. All data was anonymised where, as in the case of the students working at the university, it was not already anonymous. Consent was obtained for the noting the comments made and for the taking of photographs, which was explained in terms of wishing to keep a record of the work being done. Crucially, the observations made did not compromise the learning experience.

## **2. Data gathering strategies**

**A major tension existed between the analytical purpose of the study and, the potentially compromising aim of simultaneously capturing evidence of learning behaviours. This was resolved by taking photographs of participants, supplemented with contemporaneous notes, and classifying the pictures once the day's chemical analysis was completed.**

The primary evidence about learning behaviours of the different participating groups (see Figure1.) was provided by photographic evidence of visitors' and participants' behaviour. Interpretation of this evidence was triangulated by follow-up discussion with attendant museum and university staff. In addition, qualitative data was gathered from the transcription of verbal feedback where it was volunteered. The use of a 'visual notebook' for qualitative analysis is well-established and is considered to be especially effective in capturing the dual elements of context and phenomena (Banks, 1995). In addition, notes were taken during the public outreach days, recording visitor comments and notable incidents and these were used to triangulate the photographic data. The two work experience groups were also asked to complete evaluation questionnaires on the work they had undertaken and their progress during their time working on the project. Data from these questionnaires was used to provide additional qualitative data about the level of self-reported engagement over the whole period of involvement, whether that was one whole day or five days.

The sampling strategy was convenience sampling, as it depended on who was there when the photographs were taken. Sets of photographs were taken by the researcher or a colleague (members of museum or university staff) twice on each day of the project, of which three took place at the museum and twelve at the university. The photographs recorded the activity around the working area(s) and were taken from several angles to capture the actions and expressions of people immediately around the area(s) where analysis was being carried out. The timing of the observation was slightly variable, according to the availability of the observer taking the photographs, but occurred towards the end of the morning and mid-afternoon. Observations were made on the first day (or only day, for museum visitors) upon which participants attended; this was done to give the greatest degree of equivalence between the data capture protocol in the two markedly different environments. A regrettable limitation, imposed by the practicalities of the other demands on the availability of staff, was that this system could only capture a very small proportion of the large number of visitors (estimated as 460 by museum staff, of whom 46 were photographed) at the three separate museum-based days. The same approach was deployed with student groups but the smaller numbers (72 in total on 4 days, with 44 incidents of learning behaviour photographed)

enabled a more complete capture of the learning behaviours of the participant population. In addition to the photographs, as far as possible the researcher transcribed participant comments made during the activities, both at the museum and university. The transcriptions were then used to provide additional guidance for the classification of visual data. Whilst video recording would have enhanced the validity with which behaviours could be categorised, and captured comments made, this would have been impracticable for the researcher to combine with simultaneously supporting the analytical work, due to the greater time required for extended filming (Konecki, 2008). Nevertheless, the experiences during this project highlighted the potential benefits of video recording were similar work to be undertaken in future.

It has previously been noted that observations of a small sample can create problems in terms of the potential confounding effect of the observer's presence. However, the observers were also part of the intervention and so the effect was unavoidable. Gold (1958) noted the risk of the 'participant-as-observer' position as potentially limiting revelations and limiting objectivity by the observer. Other possible sources of error in data recall may also arise from the observer distraction by other demands on their attention, partial or faulty recall of recent observations, or the 'halo' effect brought about by differential perceptions of participants introducing bias in the interpretation of observations (Rosenthal & Jacobson, 1992). One strength of the approach to data gathering was it was undertaken in a naturalistic setting, in which the participants had elected to be. Nevertheless, to offset some of these limitations in the observations of behaviours, *ad hoc* notes of incidental observations were made in addition to the gathering of photographic evidence; although not systematic they did provide supplementary data to support the alignment of behaviours to the three-part taxonomy. Direct observation is noted as being a highly flexible mechanism for data gathering, which may be more plausible than inferred results and, in this instance, real time observations were combined with retrospective examination of photographs. Qualitative observation makes it possible to capture rich description of dynamic events (De Vaus, 2001) and the data gathering quite literally did this, through the recording of images of the phenomenon under study.

### **3. Analysing behaviours**

The approach to the analysis was *ex post facto*, since there was no control over the characteristics of the voluntary participants in any part of the project. The original intention was to use the framework to assess the observed behaviours of different classes of participants, categorised by their scientific expertise; it was only once the data was gathered that the impact of various characteristics of participants became clear. Whilst *ex post facto* work is considered poorly structured in comparison to experimental work, the nature of the outreach project from which data was gathered meant that retrospective analysis was the only approach which conserved the primary purpose of the outreach work. This naturalistic setting in which the data was gathered was essential to the project's wider aims of identifying the pharmacy contents and involving the public through outreach work. These considerations inevitably limited the options for data collection and analysis. A causal-comparative analysis was undertaken using the pre-determined typologies of participants and looking for any connection to the observed behaviours when engaging with the outreach activity. Whilst such an approach does not enable inferences to be drawn about the causes of the differences, it can be used to identify future lines of enquiry, including the degree of correlation between the features to establish which characteristics might be most strongly associated with behaviours (Fraenkel & Wallen, 2003). For reasons of pragmatism, and the diverse objectives of the project, a causal-comparison study was used, accepting that it was not possible, in consequence, to unravel more



precisely the nature of any relationships suggested by the data. At the end of each day each incidence of learning behaviour captured in a photograph was classified, in a similar way to that described by Barriault and Pearson's (2010), into one of the three levels on the taxonomy of learning behaviours. Photographs are seen as highly subjective and the taking of photographs for this work was certainly collaborative, which may have introduced an element of reflexivity from which a positive bias may have arisen, as people felt they should 'smile for the photographer' (Banks, 1995). The slightly unpredictable timing of the photography, for pragmatic reasons, may have minimised sampling bias. However, when the photos were taken by the researcher, this could only be done when all participants had settled to their tasks and were safe, which may will have caused a positive skewing of observed behaviours. This constraint applied in each of the four groups so should not have invalidated the comparison of data. Photo-elicitation provides a powerful means of corroborating the researcher's interpretation of the images with those pictured; the transient nature of participants at the public analysis events and pressures of time upon the researcher meant it was not possible to discuss photos with the subjects. Photo-elicitation was, however, possible with the other three groups and was undertaken. Although pressures on the researcher's time to support the analytical work precluded the use of video, this could have beneficially been deployed to reduce the potential loss of validity and would, very importantly, synchronously capture verbalisations uttered by the subjects. Whilst the limitations of the data capture must be acknowledged it represents the most workable compromise between gathering data or having no data at all, a dilemma which is common to many researchers (Drury & Stott, 2001) Importantly, it did permit the successful conduct of the analysis, which was the primary focus of the project.

The assignment of individual instances of recorded behaviour was undertaken by JE in consultation with university and museum staff members who had been present during the day; discussions drew on any notes and transcript data as recorded by staff. Any verbal comments, made either to staff or to other participants, and noted at the time were cross-referenced to participants visible in the photographic record, where possible. In addition, work experience students' written evaluations provided comments on their involvement in, and learning during, the project, which were used. The possibility of introducing interpretation bias was minimised as far as possible by triangulation but must be acknowledged as a possible source of distortion in the data processing (Pink, 2007). The researchers had no pre-conceived notion of how applicable the taxonomy would be or how common the learning behaviours would be between groups and so bias due to the anticipation of certain results was not felt to be likely; the unexpected findings regarding the group studying the vocational science course refuted the suggestion that data was constrained to fit a proposed theory.

The tally of each of the three different types of behaviour were recorded, as shown in the summary in Table 1.

#### **Examples of data processing**

Participant A: Photo showed him standing back from the table watching other people carrying out analytical tasks, did not comment = *initiation*

Participant B: Photo showed her carrying out one test under guidance, notes record that she then asked if she could do a test she had seen being carried out at the other end of the work area = *transition*

Participant C: Photo showed her smiling broadly as she executed a flame test. Transcript noted that she talked with excitement about how she remembered doing flame testing at school, notes record that she volunteered to test two further substances and returned, bringing other family members to try the activities = *breakthrough*

### **Characterising participants**

A number of variables were considered with respect to the different groups of participants. The structural variables were: their level of participants' prior scientific knowledge, as indicated by qualifications; the level of scientific demand of the work with which they engaged, as determined by their pre-existing knowledge; engagement with the wider cultural context, namely the museum and its desire to identify the substances; lastly, the duration of their involvement in the activities. These differences correlated due to the structure of the different elements of the analysis activity. For example, the duration of activities was determined by whether they had volunteered for the one-day public analysis or five-day work experience; this, in turn, was determined in turn by their level of pre-existing scientific knowledge. Likewise, the nature of the task was substantially different for the public and pre-16 vocational students, who had lower levels of scientific knowledge than the post-16 students. The less knowledgeable participants followed instructions in order to carry out the tests on the substance which they or the activity leaders selected. Thus, their tasks were much more closed in nature, and benefitted from significant advance preparation undertaken by the outreach leaders, such as the translation of Latin names on labels and prior selection of suitable identification tests. In contrast, the post-16 students were afforded much more autonomy, being assigned substances (some of which had no putative identity) and asked to identify them, using anything available in the university laboratories.

Another factor which distinguished participants included the degree of choice over participation. So, for the school students on the pre-16 vocational course, attendance was not voluntary for individuals; a consensus was achieved as to whether to attend but that it was a requirement that either the whole class came or the trip would not take place. In contrast, the other subjects took the decision to volunteer individually or as a small group. For other participants, conversely, attendance was voluntary.

### **Findings**

The learning behaviours of the participants were tallied after categorisation; the total number of instances of each of the three classes of behaviour evident in photographic evidence is summarised for each of the four groups of participants in Table 1. The examples of learning behaviours provided in Table 1. are drawn from observations made and noted down during the project, and are considered to be equivalent to the examples in Barriault and Pearson's (2010) original taxonomy. The data indicates that the number of participants represented by the photographs was only a small proportion of the total number of participants and that this may have reduced the representativeness, and hence discriminatory power, of the data. It also shows the large discrepancy between numbers of participants at the public event and the pre-arranged events which may also limit the reliability of the findings. Those considerations aside, there are discernible differences between the four groups in the proportions of the three levels of learning behaviours exhibited. The majority of learning behaviours at the public event were initiation and transition, with the greatest proportion at initiation level. Conversely the workshop participants showed a more even distribution of behaviours, with a slight majority occurring in the higher two levels, transition and breakthrough. Meanwhile, the vocational students exhibited almost exclusively transition and breakthrough behaviours.

Table 1.

## **Discussion of findings**

### ***1. Observed learning behaviours are a useful indicator of engagement***

The learning behaviours observed were concordant with other indicators of behaviour, in particular verbal comments. In those groups attending the one-day or five-day workshop, where self-evaluations were sought, the observed learning behaviours also broadly corresponded with the self-evaluations, and this further corroborated the plausibility of the data on learning behaviours. Although the science activities to which Barriault and Pearson's (2010) taxonomy was applied in this study were different for those to which the taxonomy was originally devised, and the duration of observation was much longer in most instances, its usefulness here indicates that it is a more generally applicable probe of engagement than that for which it was originally designed. The taxonomy was straightforward to use and staff did not find it difficult to assign learning behaviours to one of the three levels. The discrimination between the different groups was discernible (see below), although it did not provide full differentiation between the groups. For example, the proportion of initiation behaviours was the same for the one-day and five-day workshop participants. It is conceivable that the taxonomy could be refined further in future to give a still more nuanced description of the range of learning behaviours that denote different levels of engagement.

### ***2. Different categories of participants were characterised by different learning behaviour profiles***

As might be expected of participants with lower levels of scientific knowledge and correspondingly lower levels of science capital, there was a lower proportion of learning behaviours at the higher levels of learning behaviour. This decreased from approximately one half to one third to one sixth, as shown in Table 1., in a pattern that might be termed a 'pyramid of learning behaviours'. This corresponds to observations of engagement with activities by members of the public visiting a science museum (Barriault & Pearson, 2010). However, the fact that the behaviours captured represent only an estimated 10% of the visitor population means that caution must be exercised regarding the generalisability of this finding. By contrast, the school students following the vocational science course, who took part in order to fulfil assessment requirements, showed an inverse pattern of engagement, with the majority of observations showing higher level learning behaviours (over a third at transition level and nearly half at breakthrough level) than any other group observed. This pattern was especially interesting because their teachers did not consider them an academically able group and their scientific knowledge was much less than the post-16 and undergraduate students. Nevertheless, their observed behaviours indicate a very purposeful engagement with the activities and this was corroborated in other aspects of their behaviour, for instance they voluntarily devised a rota to ensure all the required tests were undertaken. This may be associated with the pupils' recognition of the cultural capital available through the qualification arising from the work; this possibility would make an interesting future study. The high level of engagement also suggests that, although not every member of the school group had voted to attend the activity, their engagement was high once they were there.

The two groups with the highest levels of scientific knowledge prior to the start of the project both showed a more even distribution of the three classes of learning behaviours, with approximately one third of each group exhibiting the different levels of learning behaviours. One explanation of this could be that they may have been migrating between levels of engagement on a cyclical basis, similar to that described by O'Brien and Toms (2008), moving from initiation to

breakthrough as they worked through successive tasks. Given the relatively small number of observations, the slight increase in 'breakthrough' behaviours exhibited by the five-day participants may not denote an appreciable shift in engagement, but the might rather be attributable to the more sustained attention which the group members were able to invest in the analysis.

The non-pyramidal distribution of observed learning behaviours in the groups with higher levels of scientific capital corroborates the notion that engagement can be promoted by existing knowledge (Campaign for Science and Engineering, 2014). However, although there may be a broad correlation between engagement with the **STEM** outreach activity and prior knowledge, they are not always proportionate, as the apparently anomalous positive engagement by the students on the vocational course suggests. This may have reflected the students' genuine interest in the applications of their scientific knowledge, albeit at a fairly basic, corresponding with their selection of a vocational course. It may also have reflected a utilitarian position relating to the need to gather evidence towards their qualification, which is viewed as 'high stake' King-Sears (2008). It would be worthwhile exploring further whether vocational **STEM** courses can raise scientific capital significantly.

### **3.Contextualised science can provide the basis of effective learning for a range of participants**

The high number of the public who voluntarily engaged in breakthrough learning behavior or better (46 in the short time scale of image capture) echoes earlier findings on the value of context-based learning of **STEM** (Ateh & Charpentier, 2014). Specifically, the scale of the task and its multi-component nature (over 300 samples to be analysed) meant that meant that the work could be sub-divided into discrete tests on different substances which could be assigned to different participants. Some could be undertaken simply, quickly and safely by passing visitors, with an assumed paucity of analytical expertise but who brought a high level of motivation towards the work and its purpose of preserving the collection. Participant responses, both through learning behaviours exhibited and verbal comments, along with the incidence of repeat visits to the activity, all indicated that these participants had found the learning experience to be a positive one. The implication of this finding is that similar work could make a useful contribution to the '95% solution' and the desired development of scientific knowledge in the general population (Falk & Dierking, 2010)

Conversely, the participants with a higher level of educational engagement in science, the post-16 students undertaking work experience in the university, had far more strategic aims in undertaking the project. Qualitative feedback from the post-16 participants indicated that the development of skills and dispositions was the main self-reported gain, rather than general interest in the project or the museum, although the context was in no way a barrier to the pursuit of their goals. Despite the many identified differences between the groups of participants, the data in Table 1. Shows that all groups exhibited learning behavior at all the three levels described by Barriault and Pearson (2010), which denoted active engagement of some level with the **STEM** learning opportunities available. Equally, there was certainly no indication that the role of context in the learning of **STEM** was detrimental to engagement, due to additional cognitive processing demands, contrary to suggestions that this may occur (Fox, Park & Lang, 2007; Johnstone, 1991). Indeed, the manifestation of learning behaviours of at least engagement level by a large number of lay participants, supports the proposal that context may provide motivation for non-specialist participants to engage with science and increase their science capital.

## **Conclusion**

- What are the key features for characterising different participants in a **STEM** outreach activity at a non-STEM venue?

The project firstly confirmed that learning behaviours, such as those described in Barriault and Pearson's (2010) taxonomy, can provide a useful way of describing varying levels of engagement with **STEM** outreach activities by different participants. The use of photographic data was found to be convenient and unobtrusive in recording behaviours, but was potentially prone to substantial distortion when retrospectively analysed. In any future work, other data capture techniques, such as video recording, would be preferred. Despite these limitations, the framework of observed behaviours served as a useful guide to levels of behaviour and one which could be used to distinguish different levels of engagement.

The level of prior **STEM** education, and associated cultural science capital, seemed to be the most influential single determinant of learning behaviours exhibited, which corroborates previous studies (Coffee, 2008). The high science capital participants were also those for whom the **STEM** of the project was the primary motivation for involvement, rather than engagement with the wider cultural dimension of the museum being the prime motivation. This pattern of higher levels of **STEM** education correlating with a greater incidence of 'transition' and 'breakthrough' behaviours was not, however, universally observed and students following a vocational course were found to exhibit a much greater incidence of high level learning behaviours than might have been anticipated from their level of STEM knowledge.

The work highlighted the value of undertaking **STEM** outreach in non-**STEM** specific venues, because of the capacity such venues offer to work with people who do not have a high level of science capital. Despite the limitations of their ability to engage independently in the scientific work, those who took part primarily because of their interest in the socio-cultural elements of the museum visit, showed positive engagement in **STEM** which served the interests of the museum collection. It might be hoped that the experience of assisting with the analysis may have increased their likelihood of engaging with future STEM activities, especially those participants who exhibited breakthrough behaviour. Whether this increase in interest in STEM can be sustained, and whether it could ultimately translate into enhanced STEM capital, was beyond the scope of this study, but merits future investigation. If this were the case, an important approach to 'growing' science capital would have been identified and one which could find expression within school through inter-disciplinary work.

## References

Archer, L., Dawson, E., DeWitt, J., Seakins, A. & Wong, B. (2015). Science capital': A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. *J. Res. Sci. Teach.*, 52, 922–948

Archer, L. & De Witt, J. (2012). 'Science Aspirations, Capital, and Family Habitus: How Families Shape Children's Engagement and Identification with Science'. *American Educational Research Journal*. 49 (5), 881–908

Archer, L. De Witt, J. & Willis, B. (2014). Adolescent Boys' Science Aspirations: Masculinity, Capital, and Power. *Journal of Research in Science Teaching*, 51(1), 1-30

Ateh, C.M. & Charpentier, A. (2014). Sustaining Student Engagement in Learning Science. *'The Clearing House'* 87, 259-263

Banks, M. (1995). Visual research methods Retrieved from:  
<http://sru.soc.surrey.ac.uk/SRU11/SRU11.html>

Barriault, C. (1999). The science center learning experience: a visitor-based framework. *The Informal Learning Review*, 35(1), 14–16.

Barriault, C & Pearson, D. (2010) Assessing Exhibits for Learning in Science Centres: A Practical Tool, *Visitor Studies*, 13 (1), 90 — 106

Berger, R, Rugen, L. & Woodfin, L. (2014). *Leaders of their own learning*. San Francisco: John Wiley and Sons

Bourdieu, P. (1986). Forms of capital. In J. G. Richardson (Ed.), *Handbook of theory and research for sociology of education* (pp. 241-258). New York: Greenwood.

Braund, M. & Reiss, M. (2004). *Learning at Museums and Hands-on Centres*, Routledge Falmer.

British Educational Research Association (2014). ethical guidelines. Retrieved from:  
<https://www.bera.ac.uk/wp-content/uploads/2014/02/BERA-Ethical-Guidelines-2011.pdf?noredirect=1>

Coffee, K. (2008). Cultural inclusion, exclusion and the formative roles of museums *Museum Management and Curatorship*, 23 (3), 261-279

Campaign for Science and Engineering. (2014). *Improving Diversity in STEM*. Campaign for Science and Engineering

Chi, B., Dorph, R. & Reisman, L. (2015). *Evidence & Impact: Museum-Managed STEM Programs in Out-of-School Settings*. Retrieved from:  
[http://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse\\_089887.pdf](http://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_089887.pdf)

Côté, J.E. and Schwartz, S. (2002). 'Comparing psychological and sociological approaches to identity: identity status, identity capital, and the individualization process'. *Journal of Adolescence*, 25, 571–586

Day, S.P. & Bryce, T.G.K. (2013) The Benefits of Cooperative Learning to Socio-scientific Discussion in Secondary School Science. *International Journal of Science Education*, 35(9), 1533-1560

De Witte, K. & Rogge, N. (2012) *Problem-based learning in secondary education: Evaluation by a randomized experiment*. Hub Research Papers, University of Leuven.

De Vaus, D. (2001). *Research Design in Social Research*. Sage Publications Ltd

Drury, J. & Stott, C. (2001). Bias as a Research Strategy in Participant Observation: the Case of Intergroup Conflict. *Field Methods*, 13(1), 47-67

Erduran, S. & Dagher, Z. (2014) *Reconceptualising the Nature of Science for Science Education: Scientific Knowledge, Practices and Other Family Categories*, Springer

Essex, J. (2013), 'Behind the scenes at the Victorian pharmacy', *Education in Chemistry*, May 2013, 26-29

Falk, J.H. & Dierking, L.D. (2000) *Learning from Museums*, Walnut Creek, CA, AltaMira Press

Falk, J.H., Moussouri, T. & Coulson, D., (1998), The Effect of Visitors' Agendas on Museum Learning, *Curator: The Museum Journal*, 41(2), 107-120

Fox, J.R., Park, B. & Lang, A. (2007). When Available Resources Become Negative Resources The Effects of Cognitive Overload on Memory Sensitivity and Criterion Bias. *Communication Research*. 34 (3), 277-296

Fraenkel, J.R. & Wallen, N.E. (2003) *How to Design and Evaluate Research in Education*. McGraw Hill Education

Gold, R. (1958). 'Roles in sociological field observation.' *Social Forces*. 36, 217-213.

Irzik, G. & Nola, R. New Directions for Nature of Science Research In Michael R. Matthews (ed.), (2014) *International Handbook of Research in History, Philosophy and Science Teaching*, (999-1021) Springer

Istomina, Z.M. (1975). 'The Development of Voluntary Memory in Preschool-Age Children, *Journal of Russian and East European Psychology*, 13(4), 5-64

Johnstone, A.H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, 7, 75-83

Kearsley, G. & Shneiderman, B. (1998). Engagement Theory: A Framework for Technology-Based Teaching and Learning. *Educational technology*, 38 (5), 20-23

Kelley, T.R. & Knowles, J.G. (2016). A conceptual framework for integrated STEM education. *Int..J. STEM Ed.* 3 (1), 1- 11

King-Sears, M.E. (2008). Facts and fallacies: differentiation and the general education curriculum for students with special educational needs *Support for Learning* · 23(2), 55-62

Konecki, K.T. (2008). Touching and Gesture Exchange as an Element of Emotional Bond Construction. Application of Visual Sociology in the Research on Interaction between Humans and Animals. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, 9(3), Art. 33, Retrieved from: <http://nbn-resolving.de/urn:nbn:de:0114-fqs0803337>

O'Brien, H.L. & Toms, E.G. (2008). What is user engagement? A conceptual framework for defining user engagement with technology. *Journal of the American Society for Information Science and Technology* 59, 6 (2008), 938-955.

Pink, S. (2007). *Doing Visual Ethnography*. Sage, London.

Ponciano, L. & Brasileiro, F. (2015). 'Finding volunteers' engagement profiles in human computation for citizen science projects'. *Human Computation*, 1 (2), 245-264

Rosenthal, R. & Jacobson, L. (1992). *Pygmalion in the classroom: Teacher Expectation and Pupils' Intellectual Development*, Crown House Publishing Ltd

Stanton-Salazar, R. D. & Dornbusch, S. M. (1995). Social capital and the reproduction of inequality: Information networks among Mexican-origin high school students. *Sociology of Education*, 68, 116-135.

Stevenson, J. (1991). The long-term impact of interactive exhibits *International Journal of Science Education*, 13 (5), 521-31

Strike, K.A. (1990). The ethics of educational evaluation in J. Millman and L. Darling Hammond (Eds) *The new handbook of teacher evaluation: Assessing elementary and secondary school teachers*, (175-190), Sage: Newbury Park, California

Suchman, E.A. (1967). *Evaluative Research: principles and practice in public service and social action programmes*, Bissell Sage Foundation, New York

Vaino, K., Holbrook, J. & Rannikmäe, M. (2012). Stimulating students' intrinsic motivation for learning chemistry through the use of context-based learning modules. *Chem. Educ. Res. Pract.*, 13, 410-419

De Vaus, D. (2001). *Research Design in Social Research*. Thousand Oaks: Sage Publications

Watts D.M. (2015). Public Understanding of Plant Biology: Voices from the Bottom of the Garden, *International Journal of Science Education, Part B*, 5 (4), 339-356

Williams, D.A. & Wavell, C., (2001). Recent research on the impact of the school library resource centre on learning. *The School Librarian*, 49(3), 123-127

Word count: 6577 words



**Table 1. The incidence of observed learning behaviours by different categories of participants**

Learning behaviour category captured in photos	Examples	Observed incidence of behaviours (total number of participants shown in brackets) by:			
		Public (460)	Half day workshop with vocational science course students (12)	One-day workshop participants (38)	Five-day work experience participants (22)
Initiation	Observing someone else doing the tests Asking about the purpose or scope of the project (by email or in person) Carrying out a one-step analysis by following the instructions provided	23	2	6	4
Transition	Doing a second test or a two-step analysis following the instructions provided Carrying out one step analysis following the instructions independently Returning later to do a further test Expressing a positive attitude to the activities e.g. 'This is interesting.'	16	4	8	4
Breakthrough	Relating the activity to prior experience e.g. 'We did something like this at school.' 'It looks like fireworks.' Testing more than one unknown substance Repeats a test for the purpose of verification/ enjoyment Communicating about the analysis with someone else Seeks a detailed explanation of the test or the project e.g. asking how we are going to deal with unsafe substances if they are discovered Developing an unscripted test e.g. using bread as a source of starch to identify iodine solution	7	5	6	5

**Figure 1. A diagram showing the differing levels of pre-existing scientific knowledge which increases L to R. whilst the level of engagement with the museum context increases R to L. The total numbers of instances of learning behaviour captured for each of the four groups of participants is shown in brackets.**



